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(71) Applicant: DEEP OCEAN ENGINEERING, INCORPORATED
12812 Skyline Boulevard
Oakland California 94610(US)

(72) Inventor: Hawkes, Graham S.
12812 Skyline Boulevard
Oakland California 94610(US)

(74) Representative: Matthews, Howard Nicholas et al,
MATTHEWS HADDAN & CO Haddan House 33 Elmfield Road
Bromley Kent BR1 1SU(GB)

(54) Method and apparatus providing tactile feedback to operators of remotely controlled manipulators.

(57) An apparatus and method is disclosed for providing tactile feedback information to the operator of a remotely operated manipulator assembly (1), such as a robot arm (2), by mechanically coupling a vibration sensitive transducer (5, 19) to said assembly (1) and audibly reproducing (7, 8, 20) the transducer output for operator listening. The use of an accelerometer (19) as a vibration sensitive transducer (5, 19) is disclosed as well as techniques for cancelling environmental noise.

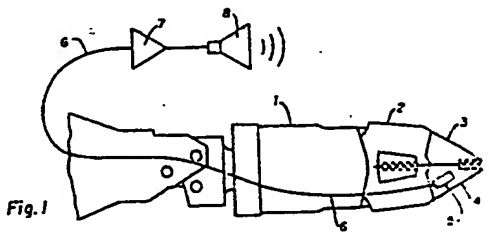

Fig. 1

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Other prior art systems utilize various transducers to sense displacement, speed, and force and use the information derived therefrom to operate a duplicate manipulator which is placed proximately to the operator for direct viewing. An additional system for providing user feedback information on force and speed is disclosed in applicant's co-pending application Serial No. 466,433, filed February 15, 1983.

The prior art discloses a number of systems for providing the user with information related to the force, speed, and displacement of the remotely controlled manipulator device. While these systems are highly useful, they do not provide the user with a sense of "touch". The great dexterity of the human hand is heavily dependent upon tactile sensitivity more commonly referred to as the sense of touch. The great importance of the sense of touch in performing delicate tasks can be clearly appreciated by observing the great reduction in dexterity which occurs when the sense of touch is dulled by cold weather or a local anesthetic. A person with very cold hands has unimpaired visual feedback, and can, through the sensing of muscle contraction and tendon displacement, obtain some information relating to manual force exerted in the hand. As is well known, however, a normally dexterous person with very cold hands will find his or her manual dexterity severely impaired due to the lack of tactile feedback from the fingertips and the other surfaces of the hand.

The prior art is noticeably lacking in devices which give the user of remotely operated manipulator devices some semblance of a sense of touch. Force, displacement, and speed feedback information is highly useful but it is not equivalent to a sense of touch. Users of such prior art systems receive little or no information relating to the texture of the objects which are being manipulated. By providing the

systems of the prior art, the present invention provides tactile feedback in the form of audible sound. The instant invention supplements the visual feedback systems of the prior art and other systems which provide force, speed, and displacement information. The essential principles of the invention can be used with all types of remotely operated manipulator systems including hydraulic, pneumatic, and electric types.

In its simplest form, the instant invention employs a microphone, accelerometer, or other vibration sensitive transducer which is mechanically coupled to the manipulator arm assembly. The electrical signal output from the transducer is amplified and, if necessary, processed and then supplied to the user through a speaker or headphone in the form of an acoustic signal. When employed in connection with manipulator arm assemblies of the type disclosed in applicant's co-pending application Serial No. 466,606, filed February 15, 1983 the usefulness and dexterity of the overall manipulator system was found to be greatly increased. The apparatus and method of the instant invention are extremely simple to implement and provide easily interpretable information which can, even to a relatively new operator, provide easily interpretable information relating to the texture, hardness, and overall "feel" of the object being touched by the manipulator.

FIGURE 1 is a block functional diagram of an apparatus employing the present invention.

FIGURE 2 is a simplified electrical schematic diagram of an embodiment of the present invention.

FIGURE 3 is a schematic block diagram of an alternative embodiment of the present employing additional transducers for noise canceling.

Figure 1 illustrates a remotely operated manipulator arm 2 of a type typically employed in undersea applications. The gripping portion of

the user additional information on actuator speeds, forces, and other related parameters of performance. It has been found, in actual use, that the focus motor of an attached video camera can be heard clearly as can the various manipulator motor drives thus giving the operator an additional means for monitoring and trouble shooting various manipulator and related or attached equipment operations.

Rigidly mounting an accelerometer to the gripping portion 2 of manipulator arm 1, greatly reduces the influence of noise in the surrounding environment. In undersea applications, environmental noise which would be deafening if sensed by a hydrophone located proximate to (but not mechanically coupled to) the manipulator assembly 1, would not have such a pronounced effect on the output of an accelerometer rigidly affixed to the arm as shown in Figure 1. The reason for this is that acoustic noise in the surrounding environment would have to be strong enough to accelerate the manipulator assembly 1 in order to produce an output from accelerometer transducer 5. Accordingly, the instant invention can provide useful information relating to the texture and other tactile features of the object which is being manipulated even in a very noisy surrounding environment. This application shows some inherent advantages of employing an accelerometer in place of an ordinary microphone which would be more sensitive to vibrations in the surrounding water unless somehow acoustically shielded.

Referring now to Figure 2, in the preferred embodiment an instrumentation accelerometer 19 is rigidly mounted on a portion of the manipulator assembly proximate to the gripping mechanism 2 similar to the mounting of transducer 5 illustrated in Figure 1. Instrumentation accelerometers typically employ a

amplifier 21 is a differential amplifier having one input 22 connected to a second vibration sensitive transducer 23 which is mounted proximate to the portion of the manipulator assembly which is producing the objectionable noise. The output from transducer 19 is connected to input 24 of differential amp 21. Transducer 19 is mounted, as previously explained, proximate to the gripping portion of the manipulator assembly so as to obtain tactile information closest to the gripping surface. The output from differential amplifier 21 is used to drive loudspeaker 8 which should, if the system is properly installed, reproduce a signal which represents the difference between the noise and the desired vibration signal sensed at the gripping surface which is a combination of noise and desirable signal. The resultant sum should be a relatively noise-free signal. Means 25, schematically illustrated as a potentiometer, can be used to vary the relative level of the transducer output signals for optimizing the noise canceling effects of the differential amplification performed by amplifier 21.

Other well-known noise canceling techniques can be used such as those employed in the commonly available noise canceling microphones used in radio communications.

second transducer (23) output, and

means (8) connected to the output of said differential amplifier (21) for audibly reproducing a signal which represents the difference between the outputs of said transducers (19, 23).

6. The apparatus of claim 5 further comprising:

means (25) for varying the relative levels of said transducer output signals for optimizing the noise canceling effects of the differential amplification performed by said differential amplifier (21).

7. The device of claim 1 wherein said transducer (19) has a substantially linear response to vibration signals over a bandwidth corresponding to the normal range of human hearing.

8. A method of providing tactile feedback information to the user of a remotely operated manipulator assembly (1) comprising:

generating an electrical signal corresponding to vibration occuring in said manipulator assembly (1), and

audibly reproducing said signal for operator listening.

9. The method of claim 8 wherein said electrical signal is produced by an accelerometer (19) mechanically affixed to said manipulator assembly (1).

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EUROPEAN SEARCH REPORT

0125895

Application number

EP 84303178.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. ³)
	DD - A - 156 784 (ROBOTRON)		B 25 J 19/02
X	* Totality *	1,2	
Y	* Totality *	8,9	
A	* Page 4, lines 22, 23 *	3,5	
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	EP - A1 - 0 066 629 (FANUC)		
Y	* Fig. 1-3; pages 4-6; claims *	1,2,8,9	
A	* Fig. 3-5 *	5	
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	DE - A1 - 2 636 473 (M.A.N.)		
Y	* Fig. 1,3-5; claims *	1,8,9	
A	* Claim 10; fig. 1; page 8, lines 20-24 *	2,3,5,6	
	--		TECHNICAL FIELDS SEARCHED (Int. Cl. ³)
	DE - A1 - 3 006 153 (KAUFELDT)		
Y	* Fig. 1-3; claims; page 11, lines 13-18 *	1,8,9	B 25 J 3/00
A	* Fig. 1-3; page 11, lines 5-12 *	3,5-7	B 25 J 9/00
	--		B 25 J 13/00
	DE - A1 - 2 934 394 (NIPPON KOGAKU K.K.)		B 25 J 15/00
A	* Fig. 1,2; claims 1,2 *	1,5,8, 9	B 25 J 19/00
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			G 08 C 25/00

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
VIENNA	17-08-1984	KRAL

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding

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